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True ileal digestible tryptophan to lysine ratios in ninety- to one hundred twenty-five-kilogram barrows¹

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ABSTRACT: Three experiments were conducted to determine the optimal true ileal digestible (TID) Trp:Lys ratio for 90- to 125-kg barrows. Basal diets contained 0.55% TID Lys and were either corn-based (Exp. 1) or corn- and soybean meal-based (Exp. 2 and 3) diets supplemented with crystalline AA. In addition, each experiment contained a corn-soybean meal control diet. The number of pigs per pen progressively increased, with pigs housed in 2 (n = 82; initial and final BW of 88.5 and 113.6 kg, respectively), 7 (n = 210; initial and final BW of 91.2 and 123.3 kg, respectively), or 20 to 22 (n = 759; initial and final BW of 98.8 and 123.4 kg, respectively) pigs per pen for each successive experiment. Pigs in Exp. 1 were fed 6 incremental additions of L-Trp, equating to TID Trp:Lys ratios of 0.109, 0.145, 0.182, 0.218, 0.255, and 0.290. For the 28-d period, there was a quadratic improvement in G:F ($P = 0.05$) and ADG ($P = 0.08$) with increasing TID Trp:Lys, characterized by an improvement in performance of pigs fed the basal diet compared with those consuming diets with a 0.145 TID Trp:Lys ratio, with a plateau thereafter as TID Trp:Lys increased. Pigs fed the control diet had less increase in backfat depth than the average of pigs

fed the titration diets (1.30 vs. 4.09 mm, respectively; $P = 0.02$), but pork quality was unaffected by dietary treatment. Pigs in Exp. 2 were fed 4 incremental additions of L-Trp, equating to TID Trp:Lys ratios of 0.130, 0.165, 0.200, and 0.235. Average daily gain and ADFI increased in a linear fashion with increasing TID Trp:Lys for the 29-d trial ($P < 0.01$), with quadratic improvements in d-29 BW ($P = 0.06$) and G:F ($P = 0.05$). Pigs fed the diet containing a TID Trp:Lys ratio of 0.165 had greater d-29 BW, ADG, G:F, and lower serum urea N concentration than pigs fed the basal diet ($P < 0.05$), but were similar to pigs fed TID Trp:Lys ratios of 0.200 and 0.235 for all criteria measured. In Exp. 3, TID Trp:Lys ratios of 0.13, 0.15, 0.17, 0.19, and 0.21 were evaluated. The response to increasing TID Trp:Lys was limited to a quadratic ($P < 0.10$) improvement in G:F with increasing TID Trp:Lys ratios. Maximum G:F was noted at a TID Trp:Lys ratio of 0.17. No relationship was noted between TID Trp:Lys and carcass characteristics. These experiments demonstrate that the minimum TID Trp:Lys ratio for pigs from 90 to 125 kg of BW is at least 0.145, but not greater than 0.17.

Key words: finishing swine, meat quality, requirement, tryptophan

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INTRODUCTION

Tryptophan is a required component of protein synthesis, functions in the formation of serotonin and melatonin, and can be a precursor for nicotinic acid. Trypto-

phan metabolism is affected by the dietary content of large neutral AA, with the ratio of Trp:large neutral AA being shown to potentially affect voluntary feed intake (Burgoon et al., 1992; Henry et al., 1992).

Tryptophan requirements have been extensively researched in nursery pigs, most recently by Guzik et al. (2002, 2005a) and Susenbeth and Lucanus (2005). Less information is available on the Trp requirements of growing (Lorschy and Patience, 1999; Eder et al., 2003)

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and finishing (Burgoon et al., 1992; Eder et al., 2003; Guzik et al., 2005b) pigs. Based on the available data, NRC (1998) estimated a total Trp requirement of 0.21% for 10- to 20-kg pigs, which was progressively lowered to an estimate of 0.11% total Trp for 80- to 120-kg pigs. These levels correspond to a Trp:Lys ratio of 0.183 in both BW ranges, an estimate similar to ideal AA ratio studies (Wang and Fuller, 1989; Chung and Baker, 1992).

Because of the relationship between dietary Trp and brain serotonin (Leathwood, 1987; Laycock and Ball, 1990; Pethick et al., 1997), dietary Trp levels may also affect pork quality (Adeola et al., 1993). Although additional Trp may increase hypothalamus serotonin, Trp supplementation has not been shown to consistently affect meat quality attributes (Henry et al., 1992, 1996; Guzik et al., 2006; Li et al., 2006).

Considering the high levels of corn in diets for late-finishing pigs and the desire to reduce N excretion through greater crystalline AA use, understanding minimal Trp:Lys levels is critical. In addition, it is unclear whether improvements in meat quality could be observed at Trp concentrations above the requirement for growth.

The objective of these studies was to evaluate the optimal Trp:Lys ratio on pig performance, serum metabolites, carcass characteristics, and pork quality in 90- to 125-kg barrows.

MATERIALS AND METHODS

All experimental procedures and animal care were approved by the University of Missouri Animal Care and Use Committee. This research consisted of 3 experiments evaluating true ileal digestible (TID) Trp:Lys ratios in late-finishing barrows (90 to 125 kg of BW).

Exp. 1

Eighty-two barrows (Monsanto Choice Genetics EB × Newsham; initial and final BW of 88.5 and 113.6 kg, respectively) were used to determine the TID Trp:Lys ratio of 90- to 125-kg barrows. Prior to reaching the target BW, the barrows were fed nutritionally adequate corn-soybean meal diets in a 4-phase, finisher feeding program. Barrows were placed in pens that provided at least 1.0 m²/pig of floor space in a mechanically ventilated finishing facility. Feed and water were supplied ad libitum, with a single-sided, 1-hole feeder and a single nipple waterer. Barrows were blocked by BW into 6 replicate pens (5 replicates for the control), with 2 barrows/pen, in a randomized complete block design. The experimental period lasted 28 d, with individual pig BW and feed disappearance recorded biweekly to calculate ADG, ADFI, and G:F. Backfat depth and LM area were measured on d 0 and 28 by using a real-time ultrasound machine fitted with a 12.5-cm, 3.5-MHz linear array transducer (Aloka SSD 500, Corometrics Medical Systems, Wallingford, CT). Images were saved to videocas-

sette tape and interpreted with AniMorph 1.41 software (Woods Hole Educational Associates, Woods Hole, MA). Subcutaneous fat measurements were determined at approximately 5.0 cm lateral to the midline, and LM area was obtained at the 10th- and 11th-rib interface.

On d 28, barrows were transported to a commercial processing plant (Excel Corp., Marshall, MO). Meat quality measurements were obtained by using procedures similar to those of Berg et al. (2003). At 45 min after exsanguination, muscle pH measurements were taken on the semimembranosus muscle (SM) and through the intercostal space into the LM at the 10th- and 11th-rib interface by using a pH-Star probe (SFK Technology, Peosta, IA). A Meat-Check probe (SFK Technology) was used to obtain an index value (PY) taken in the ham SM and LM at 45 min. The Meat-Check PY reading provides an indication of intact muscle cells based on an index of electronic conduction through lean tissue between 2 stainless-steel probe points. A low PY reading indicates a greater conduction as a result of a greater amount of free intracellular moisture and a lower proportion of intact muscle fibers. After slaughtering, hams were chilled for 24 h at 4°C, after which a measurement of light reflectance [CIE L*, a*, and b* values determined by using a Model CR-310 Minolta spectrophotometer (standardized to a white and black tile by using D65 illuminant), Minolta Corp., Ramsey, NJ] on the cut lean surface of the exposed gluteus muscle (GM; bloom time ≥10 min). The pH of the GM was also recorded at this time.

Diets for Exp. 1 are detailed in Table 1. The basal diet was a corn and AA-supplemented diet calculated to contain 0.55% TID Lys, 0.06% TID Trp, and 3.40 Mcal of ME/kg. Based on previous data (Kendall et al., 2001), a TID Lys level of 0.55% was considered marginally deficient for optimal performance, resulting in a TID Trp:Lys ratio of the basal diet of 0.109. Graded levels of L-Trp (0.02% increments) were added to the basal diet to create dietary TID Trp:Lys ratios of 0.145, 0.182, 0.218, 0.255, and 0.290. Additional crystalline AA were supplied to the basal diet, as necessary, to meet minimum AA ratio requirements, according to the pattern of Chung and Baker (1992). All diets were formulated to meet or exceed the NRC (1998)-recommended levels for minerals and vitamins. To compare the efficacy of the corn and AA-supplemented diets, a control corn-soybean meal diet formulated to contain 0.55% TID Lys, 0.14% TID Trp, and 3.39 Mcal of ME/kg was also included.

Exp. 2

Experiment 2 was conducted to determine the optimal TID Trp:Lys ratio in corn-soybean meal diets for late-finishing barrows by using 210 barrows (Triumph-4 × PIC Camborough 22; initial and final BW of 91.2 and 123.3 kg, respectively). As in Exp. 1, barrows were fed nutritionally adequate corn-soybean meal diets in a 4-phase finisher feeding program prior to reaching

Table 1. Composition of the experimental diets (as-fed basis)

Item	Exp. 1		Exp. 2		Exp. 3	
	Control diet	Basal diet	Control diet	Basal diet	Control diet	Basal diet
Ingredient						
Corn	83.39	96.144	83.321	89.765	84.01	89.94
Soybean meal, 48% CP	13.70	—	11.10	4.30	10.80	4.50
Choice white grease	1.00	1.00	3.00	2.90	3.00	3.00
Dicalcium P	0.63	0.74	0.90	0.96	—	—
Monocalcium P	—	—	—	—	0.65	0.70
Limestone	0.63	0.68	0.64	0.66	0.90	0.95
Sodium chloride	0.40	0.40	0.50	0.50	0.35	0.35
Medication ¹	—	—	0.10	0.10	—	—
Vitamin and trace mineral premix	0.25 ²	0.25 ²	0.25 ²	0.25 ²	0.10 ³	0.10 ³
Copper sulfate	—	—	0.05	0.05	0.05	0.05
L-Ile	—	0.100	—	0.056	—	—
L-Lys·HCl	—	0.455	0.111	0.329	0.12	0.31
DL-Met	—	0.009	—	—	—	—
L-Thr	—	0.163	0.028	0.122	0.02	0.10
L-Trp	—	Variable ⁴	—	Variable ⁵	—	Variable ⁶
L-Val	—	0.059	—	0.008	—	—
Calculated composition						
ME, kcal/kg	3,394	3,400	3,470	3,470	3,470	3,470
CP, %	13.6	8.7	11.7	9.3	12.2	10.0
Total Lys, %	0.64	0.60	0.63	0.61	0.63	0.62
TID ⁷ Lys, %	0.55	0.55	0.55	0.55	0.55	0.55
Total Trp, %	0.16	0.07	0.13	0.08	0.13	0.08
TID Trp, %	0.14	0.06	0.11	0.07	0.11	0.07
TID Met + Cys, %	0.52	0.37	0.49	0.41	0.40	0.36
TID Thr, %	0.46	0.43	0.45	0.44	0.39	0.39
TID Ile, %	0.55	0.36	0.44	0.37	0.41	0.33
Ca, %	0.45	0.45	0.50	0.50	0.50	0.50
Available P, %	0.15	0.15	0.19	0.19	0.19	0.19
Analyzed composition						
CP, %	13.4	8.4	12.3	9.5	12.2	10.5
Total Lys, %	0.62	0.58	0.63	0.60	0.65	0.60
Total Trp, %	0.16	0.06	0.14	0.10	0.13	0.09

¹Supplied 44 mg of lincomycin per kg of complete diet.

²Provided the following per kilogram of complete diet: vitamin A, 6,615 IU; vitamin D₃, 1,100 IU; vitamin E, 33.1 IU; vitamin K (menadione bisulfate complex), 2.9 mg; vitamin B₁₂, 0.024 mg; riboflavin, 5.1 mg; pantothenic acid, 16.5 mg; niacin, 26.5 mg; Fe (sulfate), 75 mg; Zn (sulfate), 80 mg; Mn (sulfate), 18 mg; Cu (sulfate), 10 mg; I (ethylenediamine dihydroiodide), 0.4 mg; and Se (sodium selenite), 0.3 mg.

³Provided the following per kilogram of complete diet: vitamin A, 5,512 IU; vitamin D₃, 827 IU; vitamin E, 22.1 IU; vitamin K (menadione bisulfate complex), 2.2 mg; vitamin B₁₂, 0.019 mg; riboflavin, 4.1 mg; pantothenic acid, 13.8 mg; niacin, 24.8 mg; Fe (sulfate), 116 mg; Zn (sulfate), 116 mg; Mn (sulfate), 27 mg; Cu (sulfate), 12 mg; I (ethylenediamine dihydroiodide), 0.21 mg; and Se (sodium selenite), 0.21 mg.

⁴L-Trp supplied at 0.00, 0.02, 0.04, 0.06, 0.08, and 0.10% of the diet.

⁵L-Trp supplied at 0.00, 0.0195, 0.0390, and 0.0585% of the diet.

⁶L-Trp supplied at 0.00, 0.011, 0.022, 0.034, and 0.045% of the diet.

⁷TID = true ileal digestible.

the desired target BW. Barrows were placed in pens that provided floor space of 0.7 m²/pig in a naturally ventilated finishing facility. Feed and water were supplied ad libitum with a single-sided 2-hole feeder and a single nipple waterer. Barrows were randomly allotted into 6 replicate pens of 7 barrows/pen. The experimental period lasted 29 d, with individual pig BW and feed disappearance recorded every 14 d to calculate ADG, ADFI, and G:F.

Blood samples were collected from the same 4 barrows/pen on d 0 and 27 for determination of serum urea nitrogen (SUN) and serum Trp. Blood samples were collected into tubes and centrifuged at 1,800 × g for 10 min. Serum was removed and frozen at -70°C for later analyses. Frozen serum samples were thawed at 4°C and deproteinized by using 30 mg of sulfosalicylic acid/

mL of serum. The Trp concentration of the deproteinized serum was determined by precolumn derivatization of Trp with *o*-phthalaldehyde. Separation on an Alltech adsorbosphere *o*-phthalaldehyde HR 5-μm column (150 × 4.6 mm; Alltech Inc., Deerfield, IL) was conducted by using an automated HPLC system (Beckman Coulter Instruments Inc., Palo Alto, CA) with a fluorescence detector (Jasco FP-1520, Jasco Inc., Easton, MD). Serum urea nitrogen was analyzed colorimetrically (Kit B7551-120, Pointe Scientific Inc., Lincoln Park, MI) by using a Varian Cary 50 spectrophotometer (Varian Analytical Instruments, Walnut Creek, CA).

The basal diets in Exp. 2 were corn and soybean meal based (0.55% TID Lys, 0.072% TID Trp, and 3.47 Mcal of ME/kg), resulting in a ratio of 0.130 TID Trp:Lys. Graded levels of L-Trp (0.0195% increments) were

added to the basal diet to create TID Trp:Lys ratios of 0.165, 0.200, and 0.235. As in Exp. 1, the diets were formulated to meet or exceed the NRC (1998)-recommended levels for minerals and other AA. Additional crystalline AA were supplied to the basal diet, as necessary, to meet minimum AA ratio requirements, according to the pattern of Chung and Baker (1992). A control corn-soybean meal diet formulated to contain 0.55% TID Lys, 0.11% TID Trp, and 3.47 Mcal of ME/kg was also included.

Exp. 3

Experiment 3 was conducted under commercial research conditions to validate the optimal TID Trp:Lys ratio in late-finishing barrows. Seven hundred fifty-nine barrows (Triumph 4 × PIC Camborough 22; initial and final BW of 98.8 and 123.4 kg, respectively) were fed nutritionally adequate corn-soybean meal diets in a 4-phase finisher feeding program prior to reaching the desired market BW. Barrows were housed at a density of 20 to 22 barrows per pen, providing floor space of 0.63 m²/pig in a naturally ventilated commercial finishing facility. Feed and water were supplied ad libitum with a single-sided 4-hole feeder and a single cup waterer. Pens were blocked by BW into 6 replicate pens per treatment. Blood samples were collected from the same 2 barrows/pen on d 0 and at the conclusion of the study for determination of SUN and serum Trp, as described in Exp. 2. On d 27, pen weights and feed disappearance were recorded, with the barrows subsequently being transported to a commercial processing plant (Farmland Foods, Monmouth, IL). Hot carcass weights and estimates of backfat and LM depth (Fat-O-Meater, SFK Technology) were obtained on a pen basis and used to estimate the lean percentage.

The basal diet in Exp. 3 was similar to Exp. 2 (0.55% TID Lys, 0.07% TID Trp, and 3.47 Mcal of ME/kg) with a TID Trp:Lys ratio of 0.13. Graded levels of L-Trp (0.011% increments) were added to the basal diet to create TID Trp:Lys ratios of 0.15, 0.17, 0.19, and 0.21. Only diets containing ratios of 0.13 and 0.21 TID Trp:Lys were manufactured, with the remaining diets blended, mixed, and distributed to pens with an automated feeding system (Howema Gerätebau GmbH & Co., Visbek-Wostendollen, Germany). Diets were formulated to meet or exceed the NRC (1998)-recommended levels for minerals, and other AA. Additional crystalline AA were supplied to the basal diet, as necessary, to meet minimum AA ratio requirements, according to the pattern of Chung and Baker (1992). A control corn-soybean meal diet formulated to contain 0.55% TID Lys, 0.11% TID Trp, and 3.47 Mcal of ME/kg was also included.

Statistical Analysis

Data for each response criterion were analyzed by ANOVA with the GLM procedure (SAS Inst. Inc., Cary,

NC). In Exp. 1 and 3, effects of the TID Trp:Lys ratio and block were included in the model, whereas only the effect of the TID Trp:Lys ratio was included in the model in Exp. 2. The pen was considered the experimental unit for all analyses, with linear and quadratic polynomials being used to evaluate increasing dietary TID Trp:Lys ratios. The LSMEANS procedure of SAS was used to calculate mean values, and the PDIF option was used to separate means and to test the data for potential outliers. Pairwise contrasts were performed between the control diet and the corresponding titration diet containing similar TID Trp:Lys in Exp. 2 and 3. Data from the 3 experiments were combined to estimate the optimal TID Trp:Lys ratio, by subjecting the treatment means data to least squares, broken-line methodology (Robbins et al., 2006), along with the asymptote of the quadratically fitted line by using SAS.

RESULTS

Exp. 1

Considerable improvement in performance was observed when the TID Trp:Lys was increased from 0.109 to 0.145, with final BW and ADG increased by 24% and G:F increased from 227 to 260 g/kg (Table 2). No further improvements in performance were noted with increasing TID Trp:Lys, resulting in quadratic effects for G:F ($P = 0.05$) and ADG ($P = 0.08$). Daily gain was reduced ($P < 0.05$) in barrows fed the 0.255 TID Trp:Lys diet compared with barrows fed the diets with TID Trp:Lys of 0.145, 0.182, 2.18, and 0.290. No definite cause for the reduction in ADG was established; therefore, the average of the greatest 5 titration diets was used to compare with the control. Barrows fed the control diet had greater G:F and less BF accretion ($P < 0.05$), but ADG similar to the titration diets. Increasing TID Trp:Lys did not affect pork quality attributes in the LM, SM, or GM.

Exp. 2

Data from Exp. 2 are detailed in Table 3. Increasing TID Trp:Lys linearly increased ADFI and ADG ($P < 0.01$). This was accompanied by quadratic improvements in d-29 BW ($P < 0.06$) and G:F ($P < 0.05$), characterized by an increase from ratios of 0.130 to ratios of 0.165 TID Trp:Lys and a plateau thereafter. A linear decrease was noted in SUN ($P < 0.05$), as well as a linear increase in serum Trp ($P < 0.01$). Barrows fed the 0.165 TID Trp:Lys diet had greater d-29 BW, ADG, and G:F and decreased SUN concentrations compared with barrows fed the basal diet ($P < 0.05$), but were similar to barrows fed 0.20 and 0.235 TID Trp:Lys for all criteria measured. Unlike Exp. 1, barrows fed the control diet had G:F similar to barrows fed the titration diets.

Table 2. Effects of increasing the dietary true ileal digestible (TID) Trp:Lys ratio on growth performance, carcass lean and fat, and pork quality characteristics of finishing barrows (Exp. 1)¹

Item	TID Trp:Lys							Statistics		
	Control	0.109 (basal)	0.145	0.182	0.218	0.255	0.290	LN ²	QD ²	SEM
Performance criterion										
Initial BW, kg	88.1	88.0	88.6	88.7	88.9	88.5	88.7	—	—	1.08
Final BW, kg	114.2	108.1	115.0	114.7	114.2	110.9	114.0	0.32	0.09	1.92
ADG, ³ g	932	718	945	926	925	807	906	0.31	0.08	58.6
ADFI, kg	3.26	3.16	3.63	3.56	3.51	3.17	3.56	0.80	0.44	0.180
G:F, ⁴ g/kg	286	227	260	259	258	254	254	0.12	0.05	12.0
Carcass composition										
Backfat change, ⁴ mm	1.30	3.56	4.85	4.13	5.14	2.94	3.85	0.60	0.38	0.82
LM change, cm	4.93	2.82	3.16	3.00	6.39	2.49	2.14	0.82	0.10	1.09
Pork quality measure ⁵										
Semimembranosus										
45 min PY ⁶	16.8	16.2	19.7	14.7	15.5	15.5	17.2	0.84	0.77	4.23
45 min pH	5.61	5.62	5.68	5.62	5.68	5.68	5.72	0.40	0.87	0.083
Gluteus										
CIE L* ⁷	47.7	47.3	46.1	49.4	46.5	46.2	46.6	0.65	0.65	1.74
CIE a* ⁷	11.4	12.3	11.8	12.8	12.3	12.5	12.0	0.96	0.44	0.47
CIE b* ⁷	15.4	16.4	15.5	17.0	16.4	16.4	16.1	0.92	0.61	0.26
pH	5.53	5.62	5.68	5.53	5.77	5.59	5.66	0.84	0.94	0.09
Longissimus										
45 min PY	50.2	40.6	41.7	48.0	49.3	42.2	52.6	0.20	0.89	5.60
45 min pH	5.69	5.50	5.59	5.62	5.60	5.55	5.71	0.18	0.99	0.084

¹Representing the mean of 5 (control) or 6 pens (TID Trp:Lys) per treatment with 2 barrows/pen, in an experiment lasting 28 d.

²P-values for contrasts: LN = linear; QD = quadratic.

³Pairwise comparisons of 0.255 TID Trp:Lys vs. 0.145, 0.182, 2.18, and 2.90 TID Trp:Lys, respectively ($P < 0.05$).

⁴Contrast of the control vs. the 5 greatest titration diets ($P < 0.05$).

⁵All barrows (82) were slaughtered at the end to the 28-d experiment, with the pen being considered the experimental unit.

⁶The Meat-Check PY (SFK Technology, Peosta, IA) reading provides an indication of intact muscle cells based on an index of electronic conduction through lean tissue between 2 stainless-steel probe points, with a low index value (PY) reading indicating greater conduction as a result of a greater amount of free intracellular moisture and a lower proportion of intact muscle fibers.

⁷CIE = Commission Internationale de l'Eclairage. L* = measurement of lightness to darkness, with a greater value indicating a lighter color; a* = measurement of greenness to redness, with a greater value indicating a redder color; and b* = measurement of blueness to yellowness, with a greater value indicating a more yellow color.

Exp. 3

Increasing TID Trp:Lys had no effect on ADG and ADFI (Table 4). A linear ($P < 0.05$) and a quadratic effect ($P = 0.10$) in G:F were observed with an increase in efficiency to a TID Trp:Lys ratio of 0.17, but with no further improvement through barrows fed a TID Trp:Lys ratio of 0.21. Barrows fed the control diet had greater final BW, ADG, and G:F ($P < 0.05$) compared with barrows fed the titration diets. Carcass characteristics were not affected by dietary TID Trp:Lys.

Combined Estimates

To combine data from all 3 experiments, data from each experiment were expressed as a percentage of the maximum noted in the titration diets, and subsequently analyzed. Figure 1 depicts optimal TID Trp:Lys ratios (breakpoint and maximum quadratic) based on ADG of barrows from 90 to 125 kg, using data from the 3 experiments. The ADG of barrows fed a ratio of 0.255 TID Trp:Lys ratio from Exp. 1 was considered an outlier and was removed from the analysis. The minimal breakpoint occurred at a TID Trp:Lys ratio of 0.140,

with a maximum quadratic requirement of 0.220 TID Trp:Lys. Estimates for the optimal TID Trp:Lys ratio based on G:F are depicted in Figure 2. The breakpoint occurred at a TID Trp:Lys ratio of 0.145, with the maximum quadratic at 0.216 TID Trp:Lys.

DISCUSSION

Appropriate Trp levels remain a key determinant to crystalline AA supplementation in corn-soybean meal diets because of the low concentration of Trp in corn and its relative high cost compared with other crystalline AA. The Trp:Lys ratio used in commercial diet formulations often drives dietary CP levels, thus having both economic and environmental implications. The impact of dietary CP on N excretion has been well documented, with data indicating that a CP reduction of 1.5 percentage units should reduce total N excretion by 12% (Kerr and Easter, 1995). If equivalent performance can be demonstrated at a cost savings, low-CP AA-supplemented diets would be economically advantageous. Although much research effort has been devoted to this topic in nursery pigs, less has been learned about

Table 3. Effects of increasing dietary true ileal digestible (TID) Trp:Lys ratio on growth performance and serum metabolites of finishing barrows (Exp. 2)^{1,2}

TID Trp:Lys								
Item	Control	TID Trp:Lys				Statistics		
		0.130 (basal)	0.165	0.200	0.235	LN ³	QD ³	SEM
Pig data								
Initial BW	91.2	91.1	91.2	91.3	91.0	0.85	0.55	0.37
Final BW ⁴	124.2	119.8	123.5	124.1	124.7	0.001	0.06	0.78
ADG, ⁴ g	1,140	986	1,110	1,120	1,160	0.001	0.15	27
ADFI, kg	3.40	3.25	3.41	3.43	3.52	0.009	0.61	0.063
G:F, ⁴ g/kg	335	304	327	327	330	0.001	0.05	5.0
Blood data								
Serum urea N, ⁴ mg/dL	12.66	8.94	7.67	7.24	7.18	0.02	0.32	0.45
Serum Trp, nmol/mL	59.9	31.9	47.2	62.7	71.0	0.001	0.09	0.34

¹Pig BW and performance represent a total of 210 barrows representing the mean of 7 pens of 7 barrows/pen during the 29-d experiment.

²Serum samples collected on 4 barrows/pen on d 27.

³P-values for contrasts: LN = linear; QD = quadratic.

⁴Comparison of 0.130 (basal) vs. 0.165 TID Trp:Lys ($P < 0.05$).

the practical implications of Trp:Lys ratios in late finishing pigs.

Despite the experiments being conducted at different locations with varied genotypes and pig densities, there was reasonable consistency in the response to TID Trp:Lys ratios among them. In Exp. 1, maximal gain and efficiency within the titration was attained at a TID Trp:Lys ratio of 0.145. Experiment 2 yielded a large improvement from a ratio of 0.13 to 0.165 TID Trp:Lys, with only small and nonsignificant increases in ADG at greater ratios. In Exp. 3, maximal efficiency was observed at a TID Trp:Lys ratio of 0.17. When consider-

ing all 3 experiments, no more than 0.17 TID Trp:Lys seems to be necessary to maximize performance. These estimates are somewhat lower than the 0.19 digestible Trp:Lys proposed by Lorsch and Patience (1999), which was based on the determined Trp requirement for protein deposition and an assumed apparent ileal digestible Lys requirement for protein deposition. One study with weanling pigs indicated an optimal ratio of 0.20 to 0.25 Trp:Lys (Lewis et al., 1977). Studies evaluating the ideal ratio of Trp:Lys have indicated a ratio of 0.18 to be adequate (Wang and Fuller, 1989; Chung and Baker, 1992). Data from the current studies

Table 4. Effects of increasing dietary true ileal digestible (TID) Trp:Lys ratio on growth performance, serum metabolites, and carcass measures of finishing barrows (Exp. 3)^{1,2}

Item	Control	TID Trp:Lys, %					Statistics		
		0.13	0.15	0.17	0.19	0.21	LN ³	QD ³	SEM
Pig data									
Initial BW	98.7	98.8	98.8	98.7	98.8	98.8	0.96	0.90	0.40
Final BW ⁴	124.7	122.7	122.6	123.6	122.9	123.6	0.22	0.98	0.60
ADG, ⁴ g	984	903	899	935	914	935	0.17	0.93	20.9
ADFI, kg	3.46	3.43	3.36	3.41	3.38	3.45	0.73	0.41	0.06
G:F, ⁴ g/kg	284	263	267	273	270	271	0.03	0.10	5.0
Blood data									
Serum urea N, mg/dL	11.63	8.55	8.40	8.54	7.69	8.92	0.99	0.46	0.61
Carcass measurements									
Hot carcass wt, kg	93.6	92.5	92.0	93.0	91.8	92.8	0.78	0.67	0.54
Yield, %	76.6	76.8	76.3	76.8	76.1	76.5	0.37	0.54	0.32
FOMBF, ⁵ mm	22.8	23.6	23.4	23.2	23.1	24.0	0.84	0.34	0.57
FOMLD, ⁶ mm	55.5	53.8	52.4	52.8	53.9	53.8	0.53	0.23	0.71
FOMLEAN, ⁷ %	51.6	50.9	51.2	51.3	51.5	51.1	0.61	0.30	0.34

¹All barrows (759) were slaughtered at the end to the 27-d experiment, with the pen being considered the experimental unit.

²Serum samples collected on 2 barrows/pen on d 27.

³P-values for contrasts: LN = linear and QD = quadratic.

⁴Contrast of the control diet vs. the titration diet at 0.19 TID Trp:Lys ($P < 0.05$).

⁵Fat-O-Meater (SFK Technology, Peosta, IA)-measured backfat depth, measured at a commercial processing facility (Excel Corp., Marshall, MO).

⁶Fat-O-Meater-measured loin depth measured at a commercial processing facility.

⁷Fat-O-Meater-measured lean percentage measured at a commercial processing facility.

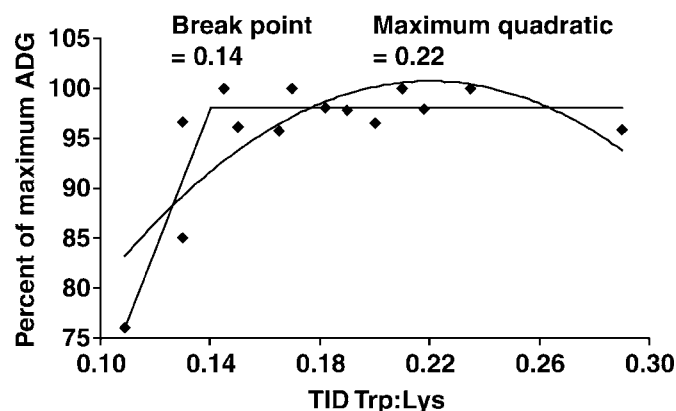


Figure 1. Fitted broken line and quadratic plot of the percentage of the maximal ADG as a function of true ileal digestible (TID) Trp:Lys in 90- to 125-kg barrows. Data points represent treatment means from 3 experiments involving 1,051 barrows. The minimal TID Trp:Lys requirement determined by broken-line analysis, using least squares methodology, was 0.140 (Y plateau = 98.0%; slope below breakpoint = -7.05% ; $R^2 = 0.84$). The data were also fitted to a quadratic equation: $Y = -1416(\text{TID Trp:Lys})^2 + 624(\text{TID Trp:Lys}) + 32.1$ ($R^2 = 0.63$). The upper asymptote of the quadratic function was calculated to be a TID Trp:Lys ratio of 0.22.

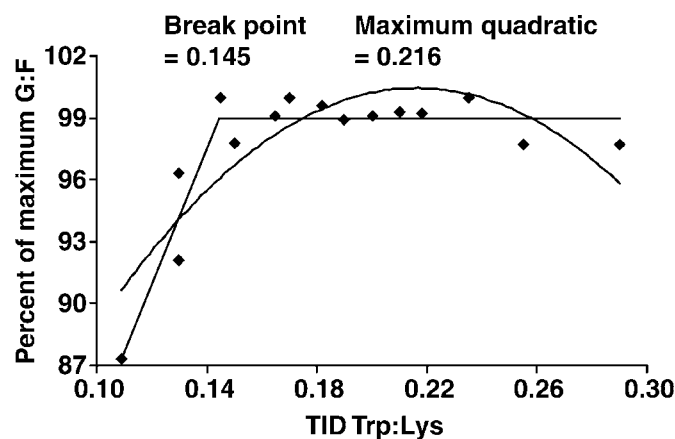


Figure 2. Fitted broken-line and quadratic plot of the percentage of the maximal G:F as a function of true ileal digestible (TID) Trp:Lys in 90- to 120-kg barrows. Data points represent treatment means from 3 experiments involving 1,051 barrows. The minimal TID Trp:Lys requirement determined by broken-line analysis, using least squares methodology, was 0.145% (Y plateau = 99.0%; slope below breakpoint = -3.30% ; $R^2 = 0.89$). The data were also fitted to a quadratic equation: $Y = -851(\text{TID Trp:Lys})^2 + 368(\text{TID Trp:Lys}) + 60.6$ ($R^2 = 0.71$). The upper asymptote of the quadratic function was calculated to be a TID Trp:Lys ratio of 0.216.

do not indicate a major change from these approximations, merely a slight downward revision of the TID Trp:Lys needs in pigs fed corn-soybean meal diets.

Three studies have evaluated the Trp requirement of late-finishing pigs. Guzik et al. (2005b) estimated a TID Trp requirement of 0.096% for pigs weighing 69.4 kg, whereas Eder et al. (2003) suggested a standardized ileal digestible Trp level between 0.084 and 0.122% by using 95% of the maximum exponential regression model for N retention and BW gain, respectively. Burgoon et al. (1992) estimated the digestible Trp requirement at 0.06% of the diet for finishing pigs. In the current study, diets were formulated to be limiting in Lys; therefore, comparisons among these studies are limited. However, at TID Trp:Lys ratios of 0.145 or 0.170, the TID Trp contents of the diet were 0.080 and 0.094%, respectively, which are comparable to these previous studies.

Ettle and Roth (2004) recently demonstrated that pigs possess some sensory recognition of dietary Trp and respond with an aversion to Trp-deficient diets. This response is one of the hallmarks of Trp deficiency and is pervasive throughout the literature. Feed intake has been shown to improve with Trp supplementation of a Trp-deficient diet in nursery (Gallo and Pond, 1966; Boomgaardt and Baker, 1973; Zimmerman, 1975; Leibholz, 1981; Borg et al., 1987; Sève et al., 1991; Burgoon et al., 1992; Han et al., 1993; Guzik et al., 2002; Eder et al., 2003), grower (Burgoon et al., 1992; Lorsch and Patience, 1999; Eder et al., 2003), and finisher pigs (Burgoon et al., 1992; Guzik et al., 2005b). In the cur-

rent study, feed intake was negatively influenced by only 2 diets, which were apparently deficient in Trp. In Exp. 1, pigs fed a ratio of 0.109 TID Trp:Lys had reduced ADFI, as did pigs fed a ratio of 0.13 TID Trp:Lys in Exp. 2. Eder et al. (2003) also observed no improvement in ADFI with increasing Trp supplementation with late-finishing pigs. This lends credence to the observation that the basal diets were only marginally Trp deficient; therefore, performance was restored after the initial additions of crystalline Trp.

Henry (1995) concluded that barrows were less sensitive to dietary Trp concentration than gilts. This was corroborated by other evidence from their laboratory (Henry et al., 1992), in which gilts had a greater reduction of ADFI when fed Trp-deficient diets than did barrows. The current study evaluated only barrows, which could explain the limited response to Trp supplementation compared with other published estimates.

Adeola and Ball (1992) suggested that short-term supplementation of Trp might be used as a management tool to reduce preslaughter stress because Trp supplementation increased hypothalamic serotonin concentrations. Although serotonin concentrations and behavioral responses could be modified by Trp supplementation, meat quality traits were not altered. In one of the few studies to demonstrate a positive meat quality response, Henry et al. (1996) observed a similar increase in hypothalamic serotonin concentrations with Trp supplementation, but greater muscle pH, suggesting a sedative effect in reducing the preslaughter

stress response. Previous studies from this group observed either no improvement in meat quality with Trp supplementation (Henry, 1995) or lower muscle pH in Trp-supplemented gilts (Henry et al., 1992), but no differences in barrows. In the barrows used in the current studies, meat quality traits were unaffected by the dietary TID Trp:Lys ratio. Although recent studies have shown alterations in serotonin and behavioral responses attributable to Trp supplementation (Koopmans et al., 2006; Li et al., 2006), there is generally no effect on meat quality characteristics (Guzik et al., 2006; Li et al., 2006).

Because the performance data were not dramatically altered by Trp supplementation in Exp. 3, it is understandable that carcass characteristics were not influenced by the TID Trp:Lys ratio. Logically, in experiments that did observe a growth and efficiency response to added Trp (Henry, 1995), there was a general increase in carcass weight and carcass components, although the lean:fat ratio was similar among treatments. This was attributed to lower energy intake, which was a result of decreased feed intake with Trp-deficient diets. If the pigs used by Henry (1995) had been slaughtered at similar BW, many of the differences in carcass traits would be expected to be diminished.

Parr et al. (2003) discussed the importance of validating basal diet formulations to ensure that no other limitations are impinging on performance. To confirm this, we elected to include control diets that were similar to our standard formulations. We were able to achieve gain and efficiency equivalent to those of pigs fed the control diet in Exp. 2; however, in Exp. 1 and 3, pigs fed the control diet had greater performance than those fed the titration diets, suggesting a dietary limitation of unknown origin. In both experiments, there was a clear response to added Trp, but the magnitude of the response could have been affected. One possible limitation is the level of dispensable AA present in the low-protein basal diets used in the current study. Recent work with nursery pigs (Kendall et al., 2004; Ratliff et al., 2004) has demonstrated a response to added dispensable AA, although the diets used in these studies were extremely low in dietary CP and very high in crystalline AA fortification. In contrast, pigs fed diets not as low in CP or AA fortification exhibited no response to dispensable AA supplementation (Kerr and Easter, 1995). Formulating a basal diet low enough in TID Trp:Lys to achieve any response to added Trp may also have created a colimitation with another AA. We chose to reduce the chance of this situation by supplementing AA, other than Trp, to an ideal AA:Lys ratio.

From these studies, the optimal ratio of TID Trp:Lys ratio was established as being between 0.145 and 0.17 for barrows fed low-CP corn- and soybean meal-based diets from 90 to 125 kg of BW. These estimates are slightly lower than NRC (1998) ratios and those of Wang and Fuller (1989) or Chung and Baker (1992). These revised estimates allow for greater flexibility in diet formulations and potentially greater utilization of

low-protein, AA-supplemented diets, and consequently on N losses into the environment.

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